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**READINESS AND RESOURCES IN THE U.S. ARMY RESERVE: A RESEARCH STUDY PLAN**

by

Daniel R. Dolk

August 1995



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# READINESS AND RESOURCES IN THE U.S. ARMY RESERVE: A RESEARCH STUDY PLAN

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## ABSTRACT

This report details a research study plan for measuring unit readiness within the U.S. Army Reserve. A review is undertaken of the current measures of operational readiness which can be categorized as asset reporting (SORTS reporting), unit modeling (Monte Carlo simulations), and functional tests (field exercises). Four key issues in Reserve readiness are identified: personnel turbulence and unit cohesion, quality of leadership, quality of training, and Reserve unit location with respect to high potential markets. A conceptual model of Reserve readiness is presented for studying these issues which addresses resources, indicators of readiness, and readiness metrics according to Betts' classification of mobilization, structural, and operational readiness. In concert with this conceptual model, an evolutionary simulation approach is proposed which relies upon genetic algorithms to generate dynamic, emergent measures of readiness rather than relying upon the subjective, static measures derived from SORTS data. Two research strategies are proposed: one for operational readiness and one for structural readiness. The first strategy has three steps: developing critical path MOS profiles for Army Reserve CFP units, determining the attrition/turnover by unit for the critical success MOS profiles, and then building a genetic simulation for generating emergent measures of unit readiness. The structural readiness research plan requires use of a geographic information system (GIS) for visual exploration of market supportability data which will lead to an analytical model for determining Reserve unit locations in high potential supportable markets.

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# 1. INTRODUCTION

The issue of military readiness has once again surged into prominence spurred by the ongoing drawdown of the Armed Services and the prospect of continued flat or declining DoD budgets. One element that is certain to draw more attention in this climate is the tradeoff between force structure and readiness. Given the higher cost of maintaining an Active versus a Reserve component soldier, arguments will inevitably arise to increase the Reserve component percentage of the total force structure at the expense of the Active forces. Counter arguments are likely to be based upon the potentially adverse effects that such a policy would have on our nation's overall military readiness. It is imperative to have a much better understanding of readiness in order to ascertain the impact of such a significant policy change. We need to know more about what readiness really entails, how to measure it, how to predict it, and what effects different resource allocation policies will have upon it.

The objective of this report is to develop a research plan for studying the relationship between resources and readiness for the Army Reserve. The plan includes development of a conceptual framework for resources-to-readiness, approaches for developing new readiness metrics and readiness predictors, and an information infrastructure for supporting the integration of data and models about readiness.

## 1.1 Sources of Information

The primary source for this report was the existing literature on military readiness. Given the rather fluid nature of the concept "readiness", the literature is either fragmented or all encompassing depending upon the scope one chooses to attribute to the phenomenon. We tried to restrict our search to articles with "readiness" mentioned explicitly in their titles, however we

did not restrict the search to just Army Reserve readiness since this literature is rather sparse. In addition to reviewing the research literature, interviews were conducted with personnel in the United States Army Reserve Command (USARC), the Office of the Under secretary of Defense (OUSD) for Personnel and Readiness, the Defense Manpower Data Center, and with several commanding officers of Contingency Force Pool (CFP) Reserve units. A CFP unit was also observed during a drill weekend.

### 1.2 The Approach Taken Here

There are two aspects to be considered in this study: readiness and resource allocation. Our attention is on the former for, until we can generate a working definition and conceptual model of readiness, it will be quite difficult to get a handle on the latter. Although people speak rather casually about "readiness", it is such a grand concept that there is little understanding or agreement on what it means. As a result, nearly everything which is done in the military can be seen as having a direct impact upon, and being integrally involved with, readiness. Retention, recruiting, family welfare, medical benefits, depot maintenance, training exercises, optempo, cohesion, and base infrastructure are just some of the factors which are claimed to be key ingredients of military readiness. In light of this dizzying array of possibilities, it is important to circumscribe what piece(s) of the overall readiness pie to investigate. During the interviews undertaken in preparation for this report, there were three areas identified as being especially critical in the Army Reserve operational readiness landscape: personnel retention/attrition, quality of training, and quality of leadership. The approach taken here is to consider these three aspects as the supporting pillars of Army Reserve operational readiness and to examine how better to understand the interaction and feedback that occurs among them *at the CFP unit level.*

Further, the issue of Reserve unit location with respect to high potential market supportability was identified as a major factor in USAR structural readiness. We also examine how to model this problem to understand better how to locate Reserve units to reduce attrition/turnover and leverage training assets.

With respect to the resource side of the coin, we focus upon the models, data, and information infrastructure necessary to relate resources to readiness. In summary our focus is on a bottom up approach to readiness coupled with a top down, USARC level of resource allocation.

## 2. OVERVIEW OF READINESS RESEARCH

Despite all the headlines and fanfare, the literature on readiness per se is surprisingly rather sparse. Citations tend to appear in outlets such as Congressional testimony, newspaper articles, Defense agency reports and publications from “think tanks” such as Rand. Only recently has there appeared a book which attempts to synthesize what we know about readiness and render it in a coherent and consistent light [Betts 1995].

### 2.1 Definitions of Readiness

*Military Readiness: Concepts, Choices, Consequences* by Professor Richard Betts of Columbia University is perhaps the most comprehensive work on military readiness in contemporary times. It is an adept analysis of the various dimensions and tradeoffs of what people commonly call "readiness". We will use the definitions derived in this book as part of the basis for developing our own framework of readiness in the next section.

Betts makes a primary distinction between three stages of readiness: operational, structural, and mobilization. We concentrate upon the first two which are most immediately

relevant to current force structure; mobilization readiness is of more historical interest, having been the linchpin of pre-Cold War defense policy. *Operational readiness* deals with various aspects of *unit status*, and is measured by the amount of time for an existing unit to attain peak combat capability. The parameters typically associated with the Status of Resources and Training System (SORTS) are directly related to operational readiness, for example, personnel fill, equipment on hand, and training exercises conducted. *Structural readiness*, on the other hand, deals with the overall force structure, and is defined as "how soon a force of the size necessary to deal with the enemy can be available" (Betts, p. 41). Relevant parameters within this context are the overall number of trained personnel, the number of formations, quantity and quality of available weapons, and distribution of combat assets across air, land and sea. A common attribute of both operational and structural readiness is the *speed,* or time in which a unit is deployed into combat. We refer to this as *mobilization.*

Betts further characterizes operational readiness in terms of efficiency and structural readiness in terms of mass, and indicates there is a basic tradeoff between making choices in favor of either mass or efficiency. A fully manned force with little training is a different beast than a smaller force that has been trained extensively. The latter is preferable for a rapid deployment contingency whereas the former may be desirable if sufficient time exists to train the force prior to combat. Fundamentally then, operational and structural readiness are in conflict with each other:

"A given pot of defense dollars can be used to buy a large force that needs time to gear up for efficient combat or a smaller force that is able to fight well at a moment's notice" (Betts, p. 43).

In the U.S. Army Reserve environment, most readiness issues are at the unit level,

therefore primarily operational in nature, and that is where we will concentrate our attention. There is one important exception, however, and that involves recruiting which is a structural readiness concern.

## 2.2 Current Measures of Operational Readiness

There are three basic conceptual approaches to operational readiness measurement at the unit level: asset reporting, unit modeling, and functional testing. Shortcomings of these measurement approaches are discussed and enumerated as presented in [Moore et al 1991].

### *2.2.1 Asset reporting*

Asset reporting is simply a straightforward accounting of resources controlled by individual units. Often this is recorded as percent fills of assets on hand compared to authorized levels. The primary vehicle for reporting readiness asset information in the Department of Defense is the Status of Resources and Training System (SORTS). SORTS provides a snapshot in time of the extent to which individual units possess the required resources and training to undertake their wartime missions. The main categories which are evaluated are manpower fill, training, equipment and supplies, and equipment condition; each category is given a C-rating which may range from C-1 (best) to C-4 or C-5 (worst); see Table 1. However, it is widely recognized that SORTS was not intended to be a readiness information system and that there are many deficiencies with respect to capturing a full profile of readiness [Gebicke 1995]. Some of these shortcomings include:

- The C-based readiness ratings reported are often subjective assessments made by the respective commanding officer;
- SORTS is not predictive; it only captures current status;

- SORTS does not provide a basis for assessing joint operations;
- SORTS is missing important factors related to readiness such as mobility; operational tempo, morale, leadership, and training exercises.

| **Readiness Rating** | **Description** |
|---|---|
| C-1 | Possesses required resources and is trained to undertake the *full* wartime mission for which it is organized or designed. |
| C-2 | Possesses required resources and has accomplished training necessary to undertake the *bulk* of the wartime mission for which it is organized or designed. |
| C-3 | Possesses required resources and has accomplished training necessary to undertake the *major portions* of the wartime mission for which it is organized or designed. |
| C-4 | Requires additional resources and/or training to undertake its wartime mission, but if the situation dictates, may be directed to undertake *portions* of its wartime mission with resources on hand |
| C-5 | Undergoing service-directed resource action and is *not prepared*, at this time, to undertake the wartime mission for which it is organized or designed. |

**Table 1. Description of SORTS Resource Category C-Levels**

All military services are required to report SORTS information for both Active and Reserve components. The Army Reserve report is detailed in AR-220 (AR-220 1992). Aggregate SORTS data are maintained for all military units by the Defense Manpower Data

Center (DMDC).

### *2.2.2 Unit modeling*

Unit modeling most often involves Monte Carlo simulation for transforming unit inputs into some form of unit outputs in a combat scenario. In this case, a unit is typically a battalion, an aircraft squadron, or a ship. Inputs include a unit's personnel strengths (numbers and skill levels) and equipment (numbers and condition); outputs generated tend to be intermediate measures of performance such as sorties flown compared to sorties scheduled, failure rates of equipment, etc. rather than final, combat-based metrics such as number of enemy targets destroyed or movement of the forward line of troops.

Each service has developed its own specific set of unit models, although the simulations are geared towards the Active forces rather than the Reserve. Some of the advantages of unit modeling include:

- Unit models predict operational capabilities and thus potentially operational readiness;
- Resource tradeoffs can be considered, e.g. the impact of more personnel versus more equipment;
- The outcome of the model runs does not depend upon subjective judgment of the unit commanders; however it does upon the assumptions of the modeler(s) which may have their own subjective bias.

Disadvantages of unit modeling include:

- Difficulty in validating models against empirical data; often the validation requires subjective judgments about whether the model is "realistic";
- Data requirements are intense and data integrity is often suspect;
- Unit models typically deal with combat units only, thus they would provide little insight into readiness of combat support service units, predominantly found in the USAR.

We did not find in the literature survey any unit models that dealt with the U.S. Army Reserve. We describe in a later section a unique kind of unit model that could be developed as a way of measuring CFP unit readiness.

### *2.2.3 Functional tests*

Functional tests attempt to measure actual unit outputs, often in the context of training exercises monitored by impartial observers. The Army Training Evaluation Program (ARTEP), for example, is a detailed set of evaluation programs which are designed to facilitate decentralized training by unit commanders. The exercises and drills comprising an ARTEP program are evaluated by nonunit personnel every 18 months for Active Army components and every four years for Reserve units. For Reserve components, the relative infrequency of evaluation coupled with high personnel turnover rates leads to a very short half life of the usefulness of these evaluations for assessing Reserve readiness. Further there is no data collection which is done in concert with ARTEP programs.

Another form of functional testing is done at the Army National Training Center at Fort Irwin, California which conducts simulated battle training exercises for battalion level units. Readiness in this context is embodied by measures of performance such as unit kill ratios. The Army Research Institute has conducted a number of studies on Army readiness using the data from these exercises which are summarized in [Holz et al 1994]. Again, the data are of limited usefulness for measuring Reserve readiness since most of the units which participate in these exercises are Active Army components, and further the exercises focus upon combat rather than combat service support units.

## 2.3 Shortcomings of Current Readiness Measures

Measures of readiness have historically been shortsighted and oftentimes tailored to meet political agendas. Current measures of readiness assume that the military is a static, mechanistic organization, the units of which can be physically measured and aggregated, and then evaluated objectively at a macro level. The SORTS database, for example, stores information about different attributes which are related to readiness, but these are primarily static, "snapshot" profiles. There is no coherent sense of how these attributes interact with one another in a dynamic mission-related context, or even whether these are the most appropriate attributes to be measuring. The analysis of readiness attributes operates more in the manner of threshold categorization procedures, that is, if enough personnel and equipment are available, then a unit is "ready". The limitations of SORTS data for providing robust readiness data is well acknowledged [Gebicke 1995; Moore et al 1991]. Nevertheless, the U.S. Army Reserve has no choice but to rely heavily upon the SORTS reporting system for making decisions which directly affect readiness of Reserve units.

In reality, readiness is a dynamic, complex process. Even at the unit level, for example, the counting of resources tells us little, if anything, about the group dynamics of a unit in terms of how well soldiers work together as a team. An understaffed unit that has trained together for a long time may actually be more ready than a fully staffed unit with high turnover that has received less training. It is difficult to capture this kind of tradeoff information by looking at current readiness data.

## 2.4 OUSD Efforts in Readiness

The issue of readiness became so visible as a result of projected DoD budgets that a

separate Office of the Under secretary of Defense for Personnel and Readiness was established in 1994. This office, headed by Lou Finch, is conducting a number of initiatives with respect to enhancing readiness reporting, identifying a robust set of readiness indicators, and clarifying resources-to-readiness links. New reporting mechanisms have been developed, namely the Joint Monthly Readiness Review where each service is required to brief the Joint Chiefs monthly on its current readiness status. Projects with DoD agencies such as the Logistics Management Institute and the Institute of Defense Analysis are intended to yield a Readiness Baseline which will provide DoD with a more comprehensive landscape of the parameters and the relationships amongst parameters which affect readiness. The Readiness Baseline is scheduled for publication in 1996 and should greatly facilitate research in this area. Additional work is being conducted to disaggregate the Operations and Maintenance budget in order to trace resource allocations to specific readiness activities.

## 3. KEY ISSUES IN USAR READINESS

Force structure is a key area when considering readiness from a strategic perspective [Betts 1995]. Maintaining a high degree of peacetime readiness in terms of being able to go to war in a short period of time requires maintenance of a large Active force which is costly to maintain. On the other hand, relying largely upon Reserve and National Guard forces during peacetime, while less costly, extracts a penalty in terms of how quickly the United States can respond to a threat. Ascertaining the readiness of Reserve units is an important factor in either scenario. Current scenarios establish the USAR as the *primary provider* of combat service support for the Army, and a *major provider* of combat support. As such, *the readiness of these*

*early deploying units in the CFP is absolutely critical for the Army to fight and win on the battlefield.*

There are many parameters which potentially affect Reserve unit readiness. Our literature survey and interviews with various Reserve and readiness personnel highlighted three general areas as especially critical to operational readiness: personnel turbulence, quality of training, and quality of leadership. Additionally, an area of immediate concern to structural readiness is the location of Reserve units with respect to high retention and recruit market supportability.

**3. 1 Personnel Turbulence and Unit Cohesion**

Reserve units are loosely coupled organizations compared to their Active Army counterparts. Because Reservists train on a part-time basis, have the mobility to transfer between units, and conduct much of their lives outside the military environment, their commitment to a particular unit is less binding than in the Active Army. One of the results of this is a dramatic personnel turnover rate (turnover = attrition + inter-unit transfers) in Reserve units, reaching as high as 45-50% annually in some instances.

The ability to field a unit which functions smoothly as a team is strongly compromised by this turbulence. Constant churning of personnel reduces team "cohesion", taxes available training resources, and creates confusion regarding trust, responsibilities, and understanding of the unit's mission. The impact upon unit readiness is particularly profound if critical MOS positions are continually turning over. High turnover in leadership positions or in full time support personnel are more likely to weaken significantly unit readiness than turbulence at the E1-E3 levels.

### 3.2 Quality of Leadership

Because of the relatively loose coupling between individuals and the organization in the Reserve environment, leadership is even more important in this context than it otherwise would be. Strong leadership is needed to strengthen the ties between individuals and their respective units. Because Reserve soldiers have more personal options than their Active counterparts, leadership has a bigger challenge in recruiting, training, and retaining people.

A current research project at the Naval Postgraduate School conducted by Professor Ken Thomas (Thomas 1995) is investigating leadership factors which may reduce attrition and turnover in the Army Reserve. These psychological and sociological factors are intended to augment the economic variables which have traditionally been used in the analysis of retention.

### 3.3 Quality of Training

Another factor contributing to attrition and turnover is the quality of training which Reserve soldiers receive. A study by (Bray and Theisen 1990) involving over 2,000 attritees lists dissatisfaction with unit training activities as the most cited reason for discontinuing drill attendance. A Unit Retention Evaluation study conducted by USARC shows training disorganization as a common theme for leaving in high-attrition TPU's (Headley 1995).

### 3.4 Reserve Unit Location and High Potential Markets

The location of Reserve units is a key issue in Reserve effectiveness and eventually in Reserve readiness. Units which are not located in, or close to, high potential markets are more vulnerable to personnel turnover since they cannot replace soldiers as easily. High retention and recruit markets in the Reserve context would include geographical locations with a relatively high density of prior service and Individual Ready Reserve (IRR) personnel which constitute the

majority of Reserve enlistees. Units which are remote from these areas may also suffer from lack of an economy of scale with respect to training and equipment resources. Soldiers either have to travel farther for their training or else training must be imported at a higher cost for a smaller number of individuals. Similarly, it may be difficult to replace or repair ageing equipment. All these factors combine to reduce operational readiness at the unit level as well as overall structural readiness.

### 3.5 Summary

Personnel turnover, leadership quality, and training quality not only impact readiness but are also interrelated. As we have indicated above, leadership quality and training quality have a direct effect upon personnel attrition. As a result, one of the two primary areas of this research effort is on the deleterious effects of high turnover on Reserve unit operational readiness. A second line of research is to study the possibly salutary effect of improved Reserve unit location upon structural readiness. Aligning and consolidating Reserve units in locations close to areas of high market supportability benefits not only the recruiting process but also may have positive effects upon Reserve retention. Thus, this may have direct impact upon both operational and structural readiness.

The relationship between these aspects of the Reserve environment and readiness require that we have some relatively concrete understanding of what readiness is and how to measure it. These are issues which are just beginning to be explored in earnest. To begin this inquiry, we need a conceptual model of readiness and their associated metrics through which we can tie the critical characteristics of Reserve units mentioned above. The following conceptual framework provides one such model and suggests an approach for studying these relationships.

## 4. FRAMEWORK FOR STUDYING USAR READINESS

Despite the intense interest in readiness, a coherent body of knowledge about this topic is only now beginning to emerge. As in any immature discipline, there are growing pains as people struggle to develop a conceptual framework, to identify relevant, timely data, and to build useful, predictive models. "When concern about the readiness issue peaks, ... confusion also peaks." [Betts, 1995]. In these early stages of growth, it is vital to develop a conceptual framework that can serve as a blueprint for thinking about readiness and for planning useful research studies.

### 4.1 A Conceptual Model of Readiness

Figure 1 depicts a simple framework for approaching the problem of resources-to-readiness. Although the "causality" of this model emanates from left to right, the explanation flows more easily in the opposite direction. The most immediate problem in readiness is what makes sense as a metric for this phenomenon. Another way of stating this challenge is, "what can we use as a dependent variable for readiness?" All that exists at present is the subjective C-rating scheme provided by SORTS which is admittedly not robust; other measures must be developed. Without them, it will not be possible to ascertain what the true indicators or predictors of readiness may be. In simplistic terms, the "regression" function needs to have both dependent and independent variables. The middle box indicates some of the possible candidates for the independent variables constituting the set of readiness indicators. Although this is not intended to be an exhaustive list, it does include the major factors which were discussed in the previous section. The left hand side of the conceptual model symbolizes the relationships between resources and readiness indicators. The causality here is roughly of the form that the more or less resources are allocated to any one of the indicators, the stronger, or weaker, that

indicator will be with respect to readiness. Thus there is a transitive relationship here going from left to right; for example, if there are less funds for training, then there will be less training available for the troops and subsequently some units will be less ready.

The following research strategy is implied from this high level model:

- First, concentrate on developing alternative metrics for readiness. This includes validating the metrics;

| RESOURCES ====> | INDICATORS / PREDICTORS ====> | METRICS |
|---|---|---|
| | Training | |
| O&M Budget | Optempo | SORTS |
| | Leadership | Unit Modeling |
| Contingency Funds | Retention | Performance Testing |
| | Equipment Maintenance | |

**Figure 1. Basic Conceptual Model for Resources to Readiness**

- Once metrics have been identified and validated, identify readiness indicators and relate them to the metrics. This can be done via various, conventional statistical techniques such as multiple regression, discrete choice analysis, and maximum likelihood estimation and/or through non-parametric techniques such as neural networks, fuzzy logic, and genetic algorithms;

- Identify the links between resources and indicators and model the impact of resource allocation changes upon the associated indicators.

In practice, elements of steps 1 and 2 will be conducted in parallel. For example, it would be difficult to devise a measurement of Army Reserve unit personnel readiness without considering potential indicators such as turnover, experience, unit location, and prior-service vs non-prior-

service mix as part of the defining process. A dynamic approach using genetic algorithms which addresses exactly this problem is described later in this report.

This simple version of a conceptual framework is a useful starting point but it does not differentiate between the various kinds of readiness as defined by Betts. We refine this by decomposing each of its elements according to the essential aspects of readiness: speed, mass, and efficiency (Figure 2).

The major difference between structural readiness and operational readiness is one of granularity. Structural readiness is concerned with the overall force structure whereas operational readiness focuses upon the unit level. At the Reserve level of analysis, the unit is clearly the logical domain of analysis. Thus the focus of our research plan at this level is upon the bottom row of this table with exclusive attention to the CFP units which form the front line of Army Reserve readiness. Specifically, the general approach is to identify research projects which help:

- identify appropriate metrics for Reserve CFP readiness;
- examine the relationships among turnover, training quality, leadership and readiness;
- trace the link between budget allocations and turnover, training quality, and leadership.

We emphasize that the intention here is to lay out a general portfolio of projects involving the major aspects of resources-to-readiness with most of the emphasis on readiness; clearly, it may not be feasible to undertake all of these projects for reasons such as data availability / accuracy, available expertise, and budget constraints.

At the structural readiness level, we identify a project aimed at clarifying the issue of unit location with respect to high potential market supportability. Although this issue is also related

to unit operational readiness in that units in areas with high market supportability are more likely to realize their personnel fills, we believe that it is more directly related to force structure issues, and therefore structural readiness.

| | RESOURCES ==> | INDICATORS ==> / PREDICTORS | METRICS |
|---|---|---|---|
| **MOBILIZATION** | - Congressional contingency funding | - Train up time<br>- Optempo<br>- Perstempo | - Mobilization time |
| **STRUCTURAL READINESS** | - Operations and Maintenance Budget | - Recruiting<br>- Market supportability<br>- Force structure<br>- Equipment on hand<br>- Depot maintenance | - #, type, and training levels of personnel<br>- # of formations<br>- Quantity/quality of weapons<br>- Distribution of combat assets |
| **OPERATIONAL READINESS** | - USARC Budget | - Quality/quantity of training<br>- Personnel turnover<br>- Quality of leadership | - Difference between potential and actual capability in force |

**Figure 2. Basic Conceptual Model for Resources to Elements of Readiness**

### 4.2 Measures of Readiness (MOR): Evolutionary Approaches to Measurement

The current status of MORs is largely subjective in nature. Although it may be desirable to introduce more objectivity into readiness metrics, it is unlikely that the subjective nature of this phenomenon can ever be eliminated completely. So, although it may be possible to derive exact counts of training hours and spare parts inventories, for example, it is not necessarily

reasonable to expect that these can be converted into exact numbers which depict states of readiness:

> "Readiness is not all of a piece; the components move at different rates and in different directions. If readiness is to be conceived broadly enough to be a basis for strategic, budgetary, and organizational choices, it must be seen as a complex system composed of numerous variables, some operating in linear and cumulative fashion, and some in a non-linear, self-negating, and cyclical way." [Betts, *Military Readiness*, p.32]

Another possible approach to this problem comes from an unexpected source, namely genetics and evolutionary biology. A related field of research has emerged therein called complexity theory which focuses on the dynamic, "bottom up" behavior of nonlinear, feedback-oriented phenomena. One of the interesting discoveries emanating from this discipline is that extremely complex behavior can emerge from an interacting population of cells each of whose behavior is governed by simple rules. Thus, the game of *Life*, now embodied in computer screensavers, consists of a rectangular grid of cells, each of which is either alive or dead, and each of which either lives or dies in the next generation according to very simple rules:

- die if there are less than 2 or more than 3 living adjacent cells,
- remain alive if there are exactly 2 or 3 living adjacent cells,
- if dead, be reborn if there are exactly 3 living adjacent cells.

This simple scheme leads to a variety of emergent behavior depending upon the initial conditions specified. Some initial configurations stabilize almost immediately while others continue evolving for hundreds of iterations. Fractals and strange attractors are other patterns which may emerge from complex behavior.

Although complexity theory has found the most receptive audience in the biological sciences, the associated technique of *genetic algorithms (GA)* has been applied across a broad

spectrum of applications, including *financial investment strategy*, economics, and game theory. Genetic algorithms were developed by John Holland and his associates [Holland 1975] at the University of Michigan as a way of modeling the self-adaptive mechanisms which living systems display.

The genetic algorithm approach is a radical departure from the straightforward "beans and bullets" method of counting resources which SORTS embodies. The GA measurement paradigm emanates from the survivability of genes as they adapt to meet the constraints of their environment. What does this have to do with military readiness? In coarse terms, the analogy is *units as genes, soldiers as chromosomes* (organized by MOS), and *readiness as fitness*. In this setting readiness will be measured as the survivability of "competing" units over successive generations as they respond to external operational requirements in the same way that biological organisms "compete" in nature for survival. This will result in a kind of internally generated metric which is independent of subjective assessment yet affords a richer comparative framework. The missing link is how to correlate unit structure with gene structure. This will be determined by the context of the problem being addressed which we discuss next.

### *4.2.1 How Genetic Algorithms Work*

The basic unit of the genetic algorithm is the *gene* which in turn consists of a fixed number of *chromosomes*. Genes form a *gene pool* which evolves over time by "adapting" to its environment by forming new genes in either of two ways:

- *crossover:* two genes split in half with each half of one gene combining with one half of the other gene (Figure 1a);
- *mutation:* one or more chromosomes in a gene are changed randomly (Figure 1b).

A *generation* occurs when every gene is either altered by crossover and/or mutation, and then selected, or rejected, on the basis of its relative fitness. The environment enters in the form of a *fitness function* which rates each of the genes with respect to some metric of fitness and removes some percentage of the least fit genes from the population.

The explicit steps of a genetic algorithm are:

1. choose a problem representation (bit patterns are the most frequent method for representing genes as shown in Figure 3)
2. initialize the population
3. calculate a fitness function for evaluating each gene
4. perform selection
5. perform crossover
6. perform mutation
7. check for convergence; if not converged, return to step 4.

#### *4.2.2 Genetic Schemas and Classifier Systems*

One extension to the representation of genes is important. The use of bit patterns usually implies that "0" in a position means the chromosome attached to that position is missing whereas a "1" implies its presence. A third option, the wildcard ("*"), is also possible, which has the meaning it doesn't matter one way or the other whether that chromosome is missing or present. This wildcard option allows the building of genetic schemas, or templates, which focus on subsets of the genetic structure. These turn out to be very useful in building *classifier systems* which allow representation of genes as rules. Thus, one can create populations of rules which can be tested for fitness in the same way that genes are.

G1 G2

*0110* 1101 **1010** 0101

G1' G2'

*0110* 0101 **1010** 1101

a) Genes G1 and G2 crossover, each left half pairing with the other's right half to form two new genes G1' and G2'.

G3 G3'

1110 0110 1010 0110

b) Gene 3 mutates, the 2nd chromosome from the left changing from 1 to 0.

**Figure 3: Crossover and mutation in genes represented as bit strings of 0's and 1's**

### *4.2.3 Application to Readiness*

The genetic algorithm simulation approach being suggested here is actually a unique kind of unit modeling readiness measurement. The notion of readiness in this context is comparable to the biological fitness of an organism to its environment. The organism in this instance is a unit whose structure consists of a specified number of soldiers with different primary MOS, specified as a genetic classifier system. The key element in making this approach work is to define a meaningful fitness, or objective, function by which to measure each unit at each

generation (iteration) of the simulation for subsequent selection and crossover / mutation.

### 4.3 Predictors of Readiness and Resources-to-Readiness: Data Exploration

The identification of indicators / predictors of readiness is the middle step of the framework. This process will undoubtedly unfold over time as OUSD and other agencies compile databases and begin developing additional metrics for readiness. Once relevant databases begin to evolve, the dominant activity will be various kinds of data exploration via parametric, non-parametric, and data visualization techniques. We have suggested one such technique, genetic algorithms, as a new approach to generating a readiness metric. In the next section, we enumerate more specific details for applying this technique to investigating the relationship between personnel turnover and operational readiness.

Another exploratory technique is the use of geographic information systems (GIS) as a way of examining data visually to identify potential correlations which can later be evaluated by more rigorous statistical analysis techniques. This approach is also spelled out in the next section with respect to investigating high potential market supportability and unit location in relation to structural readiness.

### 4.4 The Information Infrastructure: Readiness as a Network of Integrated Models

Given the breadth of topics and issues which are relevant to readiness, it is unlikely there will ever be a single, overarching readiness model. What is more likely to emerge is a *portfolio* of distributed models and databases, each of which provides some insight into one or more aspects of readiness. Thus there may be models of market recruit analysis, personnel retention, equipment inventory, depot maintenance, etc., all of which have some bearing upon readiness, and which will inevitably be built at many different geographical locations. Making sense of this

proliferation of modeling activity requires information infrastructure in the form of *distributed model management*. The Naval Postgraduate School (NPS) is proposing to OUSD and other sponsors to build *ReadiNet*, an Internet-based system for recording, sharing, executing, and integrating readiness data and model resources which research activities will eventually generate.

Internet is burgeoning as a medium for sharing information resources. There are three ways NPS is proposing to coordinate information about readiness using this medium:

1. In the short term, create a Home Page for readiness and make available an annotated bibliography available to all interested parties.

2. Over the medium term, extend this capability to accommodate sharing data and models related to readiness. In this stage, users would have access to data and models and be able to execute different scenarios with these models over the Internet. So, for example, if the Naval Personnel Research and Development Center (NPRDC) builds a model of Navy personnel readiness, it would be made available for use by other researchers via the network.

3. For the long term, the project would be extended to allow for the integration of several models so that users could, for example, link models by pipelining outputs of one as inputs to another.

The availability of ReadiNet can be a resource for sharing information about a wide range of readiness research including the projects described in the Research Plan which concludes this report.

## 5. RESEARCH STUDY PLAN

The following discussion describes in general terms two larger scale projects involving operational and structural readiness respectively, each consisting of a series of separate projects. The research structure is set up so that there is valuable return at each step of the plan regardless of whether the next step is embarked upon or not. Thus it is not necessary to buy into an "all or

nothing" undertaking for either project. The operational readiness project is fundamentally concerned with personnel attrition/turnover and unit cohesion at the CFP unit level. The structural readiness effort is concerned with the importance of Reserve unit locations with respect to high potential Reserve markets.

### 5.1 Operational Readiness at the CFP Unit Level

This work takes a systematic approach to estimating Army Reserve unit personnel readiness as a function of personnel turbulence or turnover. One of the most significant characteristics of Army Reserve units is an extremely high personnel *turnover rate*. For example, the *attrition rate* for all Army Reserve units, i.e., the rate of individuals leaving the Total Force Pool altogether, has averaged around 35-37% annually the last three years. Turnover, however, includes not only attrition but also those soldiers who stay in the Reserve but transfer between Reserve units. The annual turnover rate for this same period has averaged about 45%. Intuitively, one would expect that the higher the turnover rate in a unit, the less ready that unit is to perform its mission. On the other hand, if a unit is "stable" with respect to turnover, it may be ready despite reported shortfalls in personnel fill or equipment. Further, a "stable" unit may have less training requirements since new personnel are arriving at a less frequent rate.

Also, one would expect that not all turbulence has the same effect. It is reasonable to assume that there are critical personnel whose turnover would have much more dire consequences for a unit's readiness. For example, in the 316th Quartermaster unit, a key person in fulfilling their mission tasks is the forklift operator. While observing a drill to lay three miles of hose, it became obvious that an entire morning's activities revolved around the unloading of materials requiring skillful forklift operation. If that person, or equipment, were unavailable or

poorly trained, the mission, in all likelihood, could not be completed in an acceptable time. Turbulence in that position would have a more severe impact upon overall unit readiness than say, turbulence in those positions responsible for laying hose. (This was confirmed in a subsequent conversation with the commanding officer who confided that he was planning to train several individuals to be forklift operators for just this reason.) Other key individuals in this regard are the *full time support personnel* consisting of civilians, dual status technicians, active Guard and Reserve, and regular Army soldiers, who are assigned full time to a Reserve unit to provide administrative support for training, maintenance, supply, and personnel. The availability, or lack thereof, of full time support personnel is a related, important aspect of unit readiness. Thus, it is important to assess critical MOS personnel in the various types of units when measuring turnover.

There are three related projects which are required to attain this research objective:

1. Construct *critical success MOS profiles* for each type of CFP unit;
2. Determine the attrition/turnover for the critical success MOS profiles in each CFP unit.
3. Construct a genetic algorithm-based simulation to determine the relative readiness of these units by the number of generations which they are able to survive.

Although these projects must be conducted serially to attain the ultimate objective of analyzing the relationship between attrition/turnover and operational readiness, each intermediate step yields a useful result in its own right.

### *5.1.1 Critical Path MOS Profiles for Army Reserve CFP Units*

Identify personnel/MOSs that are critical for a unit's successful completion of its mission. There are approximately 45 different Standard Requirements Codes (SRCs) that effectively

specify what "type" a Reserve unit is (e.g., SRC=10 means a Quartermaster unit). For a subset of the SRCs (those for which unit size > 25, say), determine those personnel, including full time support personnel who are in the critical path of success (e.g., forklift operator for SRC=10). This data should be available from Army publications, USARC and/or from consulting various unit commanding officers.

### *5.1.2 Determine the Attrition/Turnover by Unit for the Critical Success MOS Profiles*

From the population of CFP units, select those which correspond to the SRCs identified in the first project. Determine unit experience level for those critical path personnel and correlate this level with SORTS personnel and training readiness measures. This will require using the SIDPERS/USAR file to construct a *unit stability profile* for each unit which takes into account the amount of time a unit has trained together with the same critical success personnel. For example, a simplistic measure would be to calculate a weighted average for all soldiers in the unit of the *time spent with current unit* with higher weights being assigned to critical success positions identified in the previous project.

### *5.1.3 Develop and Analyze a Genetic Simulation to Measure Unit Readiness*

Using the results of the second project, develop *unit classifier schemes* for each existing SRC based upon the *unit stability profile* which correlate highly with readiness. For example, a finding might be, "for Quartermaster units, a qualified forklift operator is highly correlated with good readiness ratings". Devise realistic operational requirements against which units in a "gene pool" can be evaluated and selected according to their fitness in meeting those requirements. Determine the relative readiness of units by the number of generations which they are able to survive. Compare the results of the simulations against the actual C-ratings which units were

assessed. Perform sensitivity analyses to see what factors are instrumental in changing a unit's readiness rating in this environment.

### 5.2 Structural Readiness at the USAR Level

The location of Reserve units is a key issue in Reserve effectiveness and eventually in Reserve readiness. Units which are not located in high potential markets have more trouble filling in attritions and suffer more severely from personnel turnover. Training effectiveness is also diminished for these units since there is less economy of scale. Soldiers must either travel farther for their training or else training must be provided at a higher cost for a smaller number of individuals. The location of Reserve units with respect to market supportability is therefore a key to readiness. Realigning units in conjunction with markets that have relatively high retention rates and high density of recruitable Reserve soldiers, for example, areas with a high concentration of Individual Ready Reserve (IRR) can potentially not only save money in training costs and reduced attrition but also increase operational unit readiness as well as structural readiness at the USAR level.

#### *5.2.1 Visual Exploration of Market Supportability Data*

The Critical Force Pool readiness Office (AFRC.CF) uses the MapInfo geographical information system as one of its tools for managing the readiness of the CFP units. This system is primarily used to display data during briefs to the Commanding General but is essentially limited to asset reporting. The benefit of this system could be enhanced significantly by adding recruit market information to the display which would allow visual inspection of market supportability indicators. From this enhanced capability, analysis can be conducted to determine threshold decision criteria for relocation and consolidation of current TPU's. Software utilities

can be developed in MapInfo to increase the usefulness and user friendliness of the GIS.

### *5.2.2 A Model for Determining Reserve Unit Locations in High Potential Supportable Markets*

From the visual data exploration conducted in the previous project, the foundation for an analytical model to determine Reserve unit locations in supportable recruiting markets can be built. This work can be expanded from previous research which has been done in recruit market analysis for USAREC (Thomas and Kocher 1989).

## 5.3 Summary

The Research Plan addresses two major problems in the area of readiness: personnel attrition/turnover for unit operational readiness and unit location for USAR structural readiness. Two overarching projects are described, each of which consists of constituent projects which can stand on their own as viable contributions to the USAR. The nonparametric techniques of genetic algorithms and visual data exploration are used in conjunction with traditional statistical and operations research models as the accompanying analytical engines for conducting the research.

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